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CHAPTER 3.6
SPUN-METAL PARTS

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THE PROCESS

The process of metal spinning involves the forming of sheet metal to specific circular shapes on a lathe. The sheet-metal blank rotates and is pressed against a form block of the desired shape, called a *chuck,* by means of suitably shaped spinning tools. These tools are manipulated manually (conventional spinning) or automatically (power spinning). Figure 3.6.1 illustrates conventional spinning schematically.

Although automatic conventional-spinning equipment is available, power spinning usually differs from conventional manual spinning in that the metal is worked more severely and is reduced in thickness. *Flow turning, flow forming, hydrospinning,* and *displacing spinning* are terms for this process. With power spinning of this type, the shapes that can be produced are more limited than with the conventional process,

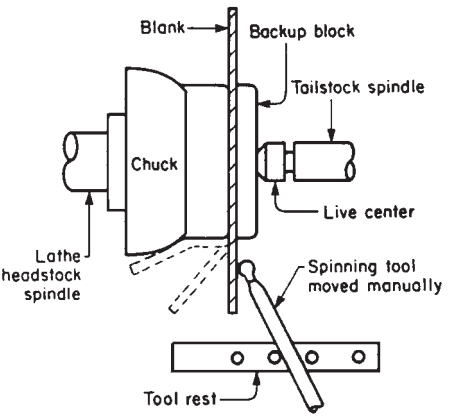

FIGURE 3.6.1 Schematic illustration of manual metal spinning.

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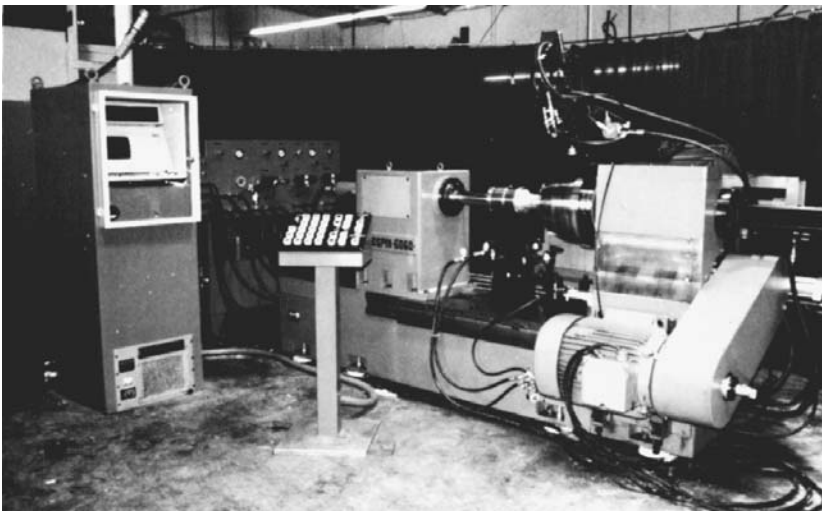

FIGURE 3.6.2 Computer-controlled power-spinning machine for heavy-walled parts. (*Courtesy Autospin, Inc.*)

which has few shape limitations. The power-spinning process also requires extremely high constant pressure. A typical power-spinning machine is shown in Fig. 3.6.2.

It is common for the hand spinner to use an additional hand tool, a *back stick,* in the left hand to keep the metal from wrinkling as it is pressed against the chuck by the spinning tool. A lubricant, brown laundry soap, Albany grease or cup grease, beeswax, petroleum jelly, etc., may be used. The chuck can be machined from hard maple wood, cast iron, brass, steel, or a fiber-composition block.

For parts with reentrant contours, i.e., shapes that are narrower at the open end than at the closed end or in the middle (e.g., a light-bulb shape), it is necessary to use a segmented chuck for small-lot production. After the part has been spun, the chuck segments, called *splits,* are removed piece by piece. If the chuck were in one piece, it would be trapped inside the spun part.

For high-production applications, some limited reentrant shapes can be made through the use of an off-center form roll instead of a segmented chuck. The roll is withdrawn from the workpiece easily after spinning has been completed.

With some forms, particularly deep forms and cylindrical shapes, and some materials, to avoid excessive stretching or stress of metals, it is necessary to use a succession of spinning operations and possibly an intermediate annealing operation before the part receives the final spinning. Intermediate-form chucks are called *breakdown chucks.*

Sometimes parts of considerable depth can be produced very economically by performing a preliminary press-draw operation on a standard set of drawing dies and then making the final shape on a spinning form. This preliminary press operation replaces the breakdown spinning operation and provides better control over metal thickness.

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FIGURE 3.6.3 Typical parts produced by metal spinning. (*Courtesy Autospin, Inc.*)

TYPICAL CHARACTERISTICS AND APPLICATIONS: SPUN-METAL PARTS

To be adaptable to spinning, an article must be symmetrical about its axis. It may be a cylinder with one or more diameters, a hemisphere, a cone, or some variation of these shapes. For practical purposes, spinnings can be as small as 6 mm ($\frac{1}{4}$ in) and as large as 4 m (12 ft) in diameter. The thickness of the metal to be spun can vary from about 0.1 mm (0.004 in) to 120 mm (4 or 5 in) on special machines and with hot material. The most common thicknesses, however, are 0.6 to 1.3 mm (0.024 to 0.050 in). Maximum thickness and size are limited only by the size of the equipment and the power available to make the metal flow.

Typical components produced by metal spinning are lamp bases, reflectors, hollowware (pitchers, tankards, vases, candlesticks, etc.), platters, pots, pans, bowls, nose cones, round trays, housings, surgical instruments, cooking utensils, aircraft parts, and components for electronic equipment. Figure 3.6.3 shows typical components which are commonly produced by metal spinning.

ECONOMIC PRODUCTION QUANTITIES

A major advantage of spinning is its extremely low tooling cost compared with the major competitive process, punch-press drawing. Since spinning tooling is simple, lead time for tooling is short, and when necessary, production on a new part can start within hours. Typically, maple chunks for parts without reentrant shapes cost only one-fiftieth as much as draw and trim dies for the same part.

Even though the unit labor cost for spun parts is much higher than that of comparable parts made on a punch press, the avoidance of a higher tooling investment makes the process attractive when low quantities are involved. Spinning is also useful in making experimental parts and preproduction samples at low cost. In an industry in which periodic styling changes are important, in the long run it may be economical to

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spin the pieces and make frequent changes in chucks rather than make expensive changes to stamping dies. Steel chucks are good for unlimited amounts of pieces. For precision work, extrathick metal pieces may be spun and then machined to final dimensions.

Generally, spinning is always advantageous when quantities are low or uncertain. It may be preferable for quantities as high as 5000 or more if draw dies for a part are particularly expensive, if lead time is critical, or if power-spinning equipment is available.

SUITABLE MATERIALS FOR SPINNING

The suitability of metals for spinning parallels their suitability for other cold-forming operations. Ductility is the prime prerequisite. Another desirable property is a minimum tendency to work-harden. When a material lacks these properties, annealing between operations is necessary. A popular material for spun parts is 2S aluminum because it possesses both properties. Soft copper is another preferred choice for the same reasons.

For convenience of reference, Table 3.6.1 indicates the relative spinnability of various commercially available metals. A rating of 100 indicates maximum suitability for the type of spinning indicated, while lower rating values indicate proportionally less ease of forming with spinning methods. Note that in some cases (e.g., brass) an average value for a number of alloys has been indicated. Specific alloys and specific parts designs and spinning conditions may involve values different from those shown.

DESIGN RECOMMENDATIONS

In spinning, the conical shape is the easiest to form and the most economical. The metal is not subjected to such severe strain when worked down to its extreme depth because the angle at which the chuck meets the metal is small and allows better control of the metal during the spinning operation. The hemispherical shape is more difficult to spin because the angle grows increasingly sharper as the metal is forced farther back on the chuck. In spinning a cylinder, the metal is exposed to greater strain because of the sharp angle. This operation requires more time and skill. (See. Fig. 3.6.4 for an illustration of these basic shapes.)

Manual metal spinning is a versatile process, and spun parts have few shape restrictions except for the basic limitations of circular cross section. The following design recommendations, therefore, are not mandatory rules but rather suggestions for promoting ease of manufacture:

1. Blended radii and fillets are preferable to sharp corners for ease of spinning. Sharp corners tend to cause thinning of stock and, in the case of external corners, breakage of wood or masonite chucks. A desirable minimum is 6 mm ($\frac{1}{4}$ in), although 3 mm ($\frac{1}{8}$ in) usually causes no problems. (See Fig. 3.6.5.)
2. If the part has cylindrical sides and a wood chuck is used, allow a taper of 2° or more, if possible, to facilitate removal of the part from the chuck. With steel chucks, less taper is required; as little as $\frac{1}{4}$° will be satisfactory.
3. If desired, a stiffening bead can be rolled on the edge of the spun shell. It is

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TABLE 3.6.1 Spinnability of Various Materials

Metal	UNS designation	Manual spinning[a]		Power spinning[b]		
		Shallow or flat shapes[c]	Severe or deep shapes[d]	Shallow, 40–90°	Medium, 25–40°	Severe, 11–25°
Group I: Aluminum and alloys						
Non-heat-treatable						
1100-0	A91100[h]	100	100			
3003-0	A93003[h]	100	99			
3004-0	A93004[h]	100	90	100	75	50
5052-0	A95052[h]	90	65			
5086-0	A95086[h]	88	75			
Heat-treatable						
2014-0	A92014[h]	75	60[e]			
2024-0	A92024[h]	65	45	100	95	65
6061-0	A96061[h]	95	85			
Group II: Copper and alloys						
Copper	Various	100	92	100	90	80
Brass	Various	95	75	100	80	75
Bronze	Various	90	60	90	70	45
Group III: Steels						
Low-carbon 1010 to 1020	G10100 to G10200	100	95	100	95	90
SAE 4130	G41300	80	50[e]	90	75	NA
Galvanized (electrolytic coatings)		100	80	100	90	NA
4340	G43400	75	45[e]	85	70	NA
AISI-8630	G86300	70[e]	40[e]	NA	NA	NA
Tricent 4405 (modified 4340)	G43406	75	45[e]	85	70	NA
Group IV: Stainless steels						
Unstabilized types						
202	S20200	100	78	100	92	85
302	S30200	98	80			
304	S30400	98	90	100	95	90
305	S30500	100	100			
Stabilized types						
316 (molybdenum)	S31600	90	60			
321 (titanium)	S32100	85	50	98	90	80
347 (columbium)	S34700	90	50			
17-7 PH	S17700	80[e]	60[e]	70[e]	NA	NA
Straight chromium types						
405	S40500	90	70	90	80	70
410	S41000	90	70			
430	S43000	90	50			
446	S44600	50[e]	35[g]			
Magnetic shielding alloys, Mumetal, 1950, etc.		95	70	100	85	65

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TABLE 3.6.1 Spinnability of Various Materials (*Continued*)

Metal	UNS designation	Manual spinning[a] Shallow or flat shapes[c]	Manual spinning[a] Severe or deep shapes[d]	Power spinning[b] Shallow, 40–90°	Power spinning[b] Medium, 25–40°	Power spinning[b] Severe, 11–25°
Group V: Nickel and nickel alloys						
Monel	Various	100	88	100	92	NA
Inconel 800	N08800	90	70	90	80	NA
Inconel 702	N07702	85	60	NA	NA	NA
Incoloy 801	N08801	80	55	NA	NA	NA
Inconel X	N07750	90	50	NA	NA	NA
A-286	S66286	70[e]	60[e]	NA	NA	NA
Nickel	Various	100	92	NA	NA	NA
HastelloyB	N10001	75	35	90	75	60
HastelloyC	N10002	50	10	90	75	60
HastelloyX	N06002	NA	NA	90	75	60
Group VI: Miscellaneous						
Lead		96	90	NA	NA	NA
Pewter	L13912 L13911	100	99	NA	NA	NA
Zinc		100	100	NA	NA	NA
Tantalum		86	45	NA	NA	NA
Magnesium		80[e]	70[g]	90[e]	80[e]	70[e]
Molybdenum		75[e]	35[e]	NA	NA	NA
Titanium[e,g]		60	25	90	85	75

Note: NA, not available. Much experimental and development work is in progress, but definite ratings are not yet available.

[a]Manual or conventional spinning using hand or lever tools.

[b]Power spinning is basically for conical shapes in which the spinning-roll power is applied through mechanical or hydraulic setups. Angles shown are from sidewall to centerline (one-half the included angle).

[c]Shallow or flat shapes are relatively shallow contours or simple flanges, dish shapes, etc.

[d]Severe or deep shapes are parts that have extreme deformation of blank, tending toward cylindrical contour.

[e]Spinnings are made at elevated temperatures.

[f]Nature of this alloy necessitates very frequent intermediate annealing.

[g]No lubricant is needed when hot-spinning titanium at 1150 to 1250°F.

[h]0-temper (annealed).

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preferable, from a production standpoint, to have the bead face outside rather than inside the part. Otherwise, rechucking in a hollow external chuck will be necessary because both inside and outside beads are formed "in air" with no chuck support; bead dimensions should be loosely toleranced. (See Fig. 3.6.6.)

4. Use as shallow a part design as possible; i.e., avoid deep cylindrical designs, which require repeated operations and annealing. A spinning ratio (depth-to-diameter ratio) of less than 1:4 is preferable. Spinning ratios are classified as follows:

Shallow: less than 1:4 Moderate: 1:4 to 3:4 Deep: 3:4 to 5:4

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SPUN-METAL PARTS

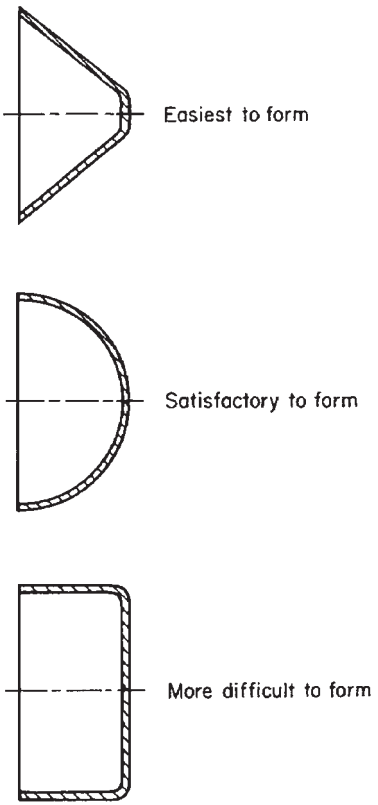

FIGURE 3.6.4 Comparison of basic spun shapes arranged in order of ease of spinning.

5. Internal flanges and other configurations of reentrant shapes, as mentioned earlier, are more costly to produce because they require special, more complex chucks or spinning without backup support for the work. (See Fig. 3.6.7.)
6. Dimension parts to surfaces adjacent to the chuck (usually inside dimensions). This allows the chuck maker to apply these dimensions directly to the chuck, and it avoids variations in diameter or length caused by variations in material thickness. (See Fig. 3.6.8.)
7. Since some thinning of material is normal in conventional metal spinning, this should be allowed for if final wall thickness is critical. Specifying material 25 or 30 percent thicker than the finished-part thickness is usually sufficient to allow for such reduction in wall thickness.
8. However, material too thick for easy spinning should not be specified. Both extra-thick and extra-thin materials make spinning more difficult. See Table 3.6.2 for recommended stock thicknesses for best spinnability.
9. Avoid reverse-form designs, if possible, because they require additional operations and can cause considerable thinning of stock. (See Fig. 3.6.9.)

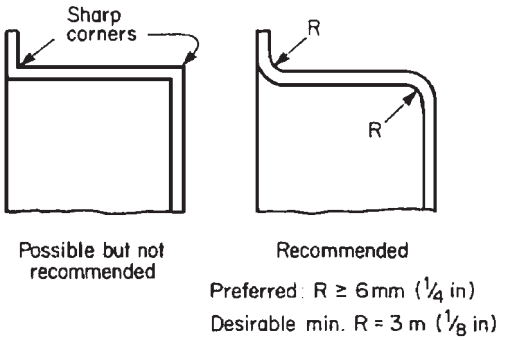

FIGURE 3.6.5 Sharp corners in spun parts are possible but should be avoided.

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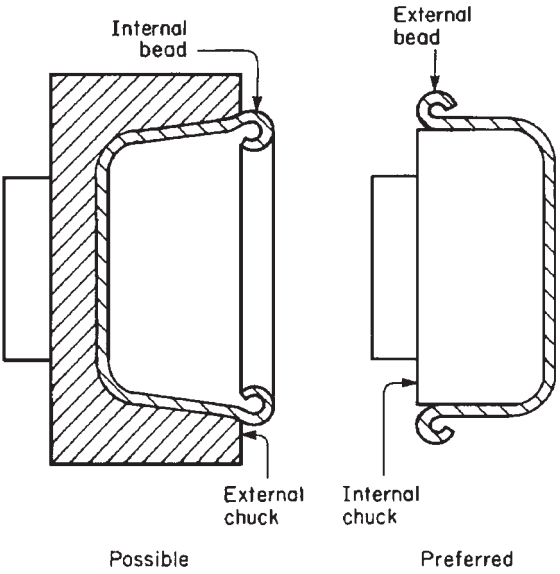

FIGURE 3.6.6 Beads placed on the outside of a part are more economically spun than beads on the inside.

10. The flatness of a flat-bottomed part will not be improved by the spinning operation. If bottom rigidity is important (freedom from "oil canning") and flatness is not required, a cone angle of 5° will provide rigidity and is easy to spin.

TOLERANCES

Table 3.6.3 presents recommended minimum dimensional tolerances for conventionally spun parts. Table 3.6.4 provides similar data for power-spun parts.

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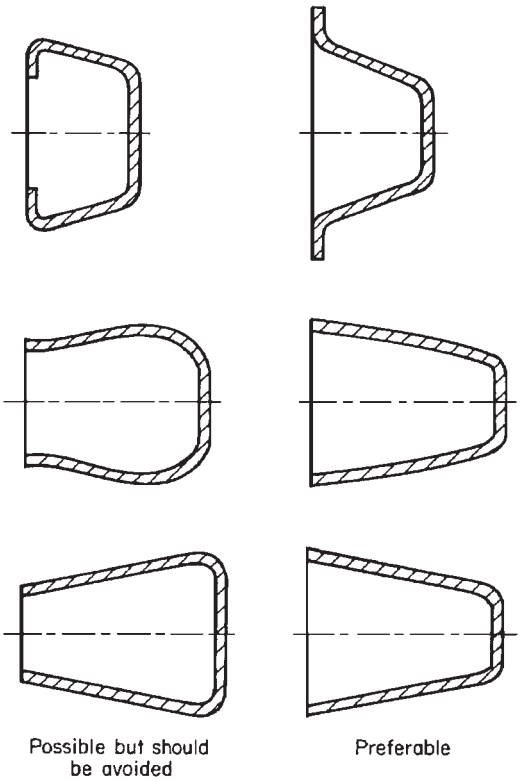

FIGURE 3.6.7 Avoid reentrant shapes, if the design purpose permits, because they add to the part cost.

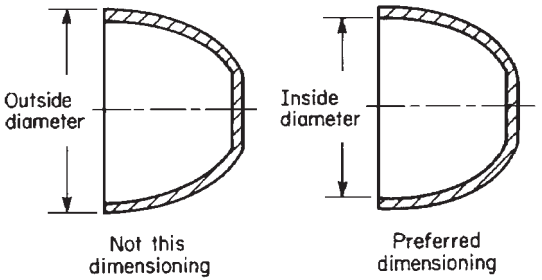

FIGURE 3.6.8 Spun shapes should normally be dimensioned to the surface that touches the chuck.

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TABLE 3.6.2 Recommended Stock Thickness for Easy Spinning

	Recommended stock thickness, mm (in)			
	Aluminum		Steel	
Blank diameter, mm (in)	Minimum	Maximum	Minimum	Maximum
Less than 100 (less than 4)	0.6 (0.025)	1.2 (0.045)	0.5 (0.020)	1.0 (0.040)
Over 100 to 500 (over 4 to 20)	0.8 (0.032)	2.0 (0.080)	0.6 (0.025)	1.5 (0.063)
Over 500 (over 20)	1.0 (0.040)	3.0 (0.125)	0.8 (0.032)	2.0 (0.080)

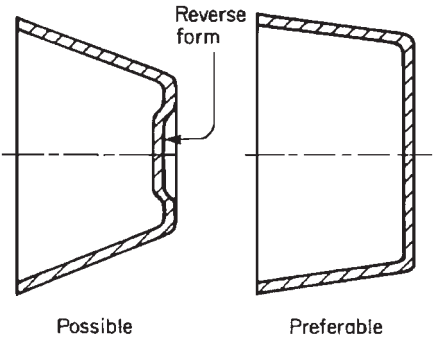

FIGURE 3.6.9 Avoid reverse bends, if possible, because they necessitate multiple spinning operations with separate chucks.

TABLE 3.6.3 Recommended Tolerances for Conventional Spinning

Nominal dimension	Diameters, mm (in)	Depths, mm (in)	Angles, °
Under 40 mm (under 1.6 in)	±0.25 (0.010)	±0.4 (0.016)	±1
40–125 mm (1.6–5.0 in)	±0.4 (0.016)	±0.8 (0.030)	±3
125–500 mm (5–20 in)	±0.8 (0.030)	±0.8 (0.030)	±3
500 mm–1 m (20–40 in)	±1.5 (0.060)	±1.1 (0.044)	±5
1–2 m (40–80 in)	±3 (0.120)	±1.5 (0.060)	±5
Wall thickness, mm (in)		Recommended tolerances, mm (in)	
Under 1.3 (0.050)		+0.13 (0.005), −0.38 (0.015)	
Under 2.5 (0.100)		+0.25 (0.010), −0.63 (0.025)	
Over 2.5 (0.100)		+0.25 (0.010), −1.3 (0.050)	

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TABLE 3.6.4 Recommended Tolerances for Power-Spun Parts

	Recommended tolerances, mm (in)	
Dimension	Tight	Normal
Diameter, 0–150 mm (0–6 in)	±0.05 (0.002)	±0.13 (0.005)
Diameter, over 150 mm (6 in)	±0.08 (0.003)	±0.20 (0.008)
Length	±0.13 (0.005)	±0.25 (0.010)
Wall thickness	±0.05 (0.002)	±0.13 (0.005)

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